DIGITAL TELEVISION TRANSMITTER AND RECEIVER FOR USING 16 STATE TRELLIS CODING

Description

Technical Field

The present invention relates to a Vestigial Side Band (VSB) digital television (DTV) transmitter and receiver based on terrestrial DTV Standards, which is A/53 of the Advanced Television System Committee (ATSC), and a method thereof. More particularly, it relates to a DTV transmitter and receiver using 16-state trellis coding, and a method thereof.

Background Art

The standards of the Advanced Television System Committee (ATSC) suggest to use a signal obtained by modulating 12 independent data streams, which are trellis encoded and time-multiplexed, into 10.76 MHz-rate 8-level Vestigial Side Band (VSB) to transmit High Definition Television (HDTV) broadcasting through a terrestrial broadcasting channel. The frequency band of the signal is transformed into a frequency band of 6MHz which corresponds to a standard Very High Frequency (VHF) or Ultrahigh Frequency (UHF) terrestrial television channel. Signals of the corresponding channel are broadcasted at a data rate of 19.39Mbps. Detailed technology on the ATSC DTV standards and A/53 are available at http://www.atsc.org/.

Fig. 1 is a block diagram showing a conventional DTV transmitter. As shown, data inputted into a transmitter 100 are serial data streams formed of 188-byte Moving Picture Experts Group (MPEG) compatible data packets, each of which includes a synchronous byte and 187-byte payload data. The inputted data are randomized in a data randomizer 101 and each packet is encoded to include 20-

byte parity information for forward error correction (FEC), FEC-Reed Solomon (RS) coding, 1/6 data field interleaving, and 2/3 trellis coding. That is, according to the ATSC standards, the data randomizer 101 performs XOR on the payload data bytes inputted to a pseudo random binary sequence (PRBS) having a maximum length of 16 bits, which is initialized at a starting field of a data field.

In the RS encoder 103 receiving the outputted randomized data, data having a total of 207 bytes are generated for each data segment by adding 20 RS parity bytes for FEC to the 187 bytes.

The randomization and FEC are not performed on synchronous bytes corresponding to a segment synchronous signal among the inputted packet data.

Subsequently, data packets included in consecutive segments of each field are interleaved in a data interleaver 105, and the interleaved data packets are interleaved again and encoded in a trellis encoder 107. The trellis encoder 107 generates a stream of a data symbol expressed in three bits by using two bits input. One bit of the inputted two bits is pre-coded and the other bit is 4-state trellis encoded into two bits. The three bits finally outputted are mapped to an 8-level symbol. The trellis encoder 107 includes 12 parallel trellis encoders and precoders to generate 12 interleaved/coded data sequences.

The 8-level symbol are combined in a multiplexer (MUX) 109 with segment and field synchronization bit sequences 117 from a synchronization unit (not shown) to form a transmission data frame. Subsequently, a pilot signal is added in a pilot adder 111. Symbol streams go through VSB suppressed-carrier modulation in a VSB modulator 113. An 8-VSB symbol stream of a baseband is finally converted into a radio frequency (RF) signal in an RF converter 115 and then transmitted.

Fig. 2 is a block diagram describing a conventional DTV receiver 200. As illustrated, a channel for the RF signal transmitted from the transmitter 100 is selected in a tuner 201 of the receiver 200. Then, the RF signal goes through intermediate frequency (IF) filtering in an IF filter and detector 203 and a synchronous frequency is detected. A synchronous and timing recovery block 215 detects a synchronous signal and recovers a clock signal.

Subsequently, the signal is removed of a National Television Systems Committee (NTSC) interference signal through a comb filter in an NTSC removing filter 205, and equalized and phase-tracked in an equalizer and phase tracker 207.

An encoded data symbol removed of multi-path interference goes through trellis decoding in a trellis decoder 209. The decoded data symbol is deinterleaved in a data deinterleaver 211. Subsequently, the data symbol is RS decoded in an RS decoder 213 and derandomized in a data derandomizer 217. This way, the MPEG compatible data packet transmitted from the transmitter 100 can be restored.

Fig. 3 is a diagram illustrating a transmission data frame exchanged between the transmitter of Fig. 1 and the receiver of Fig. 2. As illustrated in the drawing, a transmission data frame includes two data fields and each data field is formed of 313 data segments.

The first data segment of each data field is a synchronous signal, i.e., a data field synchronous signal, which includes a training data sequence used in the receiver 200. The other 312 data segments include a 188-byte transport packet and 20-byte data for FEC, individually. Each data segment is formed of data included in a couple of transmission packets due to data interleaving. In other words, the data of each data segment correspond to several transmission packets.

Each data segment is formed of 832 symbols. The first

four symbols are binary and they provide data segment synchronization. A data segment synchronous signal corresponds to a synchronous byte, which is the first byte among the 188 bytes of the MPEG compatible data packet. The other 828 symbols correspond to 187 bytes of the MPEG compatible data packet and 20 bytes for FEC. The 828 symbols are transmitted in the form of an 8-level signal, and each symbol is expressed in three bits. Therefore, 2,484 bits (=828 symbols x 3 bits/symbol) are transmitted per data segment.

However, transmission signals of a conventional 8-VSB transceiver are distorted in indoor and mobile channel environments due to variable channel and multipath phenomena, and this degrades reception performance of the receiver.

In other words, transmitted data are affected by various channel distortion factors. The channel distortion factors include a multipath phenomenon, frequency offset, phase jitter and the like. To compensate for the signal distortion caused by the channel distortion factors, a training data sequence is transmitted every 24.2ms, but a change in multipath characteristics and Doppler interference exist even in the time interval of 24.2ms that the training data sequences are transmitted. Since an equalizer of the receiver does not have a convergence speed fast enough to compensate for the distortion of receiving signals, which occurs by the change in multipath characteristics and the Doppler interference, the receiver cannot perform equalization precisely.

For this reason, the broadcasting program reception performance of 8-VSB DTV broadcast is lower than that of an analog broadcast and reception is impossible in a mobile receiver. Even if reception is possible, there is a problem that a signal-to-noise ratio (SNR) satisfying Threshold of Visibility (TOV) increases.

To solve the problems, International publication Nos. WO 02/080559 and WO 02/100026, and U.S. Patent publication No. US2002/019470 disclose technology for transmitting robust data by any one among 4-level symbols, e.g., {-7,-5,5,7} or {-7,-3,3,7}. Since the symbols to which robust data are mapped are limited in the conventional technology, there is a problem that the average power of the symbols corresponding to the robust data is increased compared to conventional 8-VSB method. In other words, when robust data are transmitted by any one among four level symbols {-7,-5,5,7}, symbol average power is 37 energy/symbol, or if robust data are transmitted by any one among four level symbols {-7,-3,3,7}, symbol average power is 29 energy/symbol, which signifies that the average power of the symbol corresponding to the robust data is increased compared to the conventional 8-VSB method. The increase in the symbol average power leads to increase in the entire average power. When signals are transmitted with a limited transmission power, which is true in most cases, the transmission power of normal data are relatively reduced compared to the conventional 8-VSB method and, thus, there is a problem that the normal data have poorer reception performance than the conventional 8-VSB method in the same channel environment.

Since the problem becomes more serious when the ratio of robust data mixed with normal data is increased, the SNR satisfying the TOV is increased. Accordingly, the reception performance is degraded, even though the channel environment is fine and it is likely to happen that backward compatibility cannot be provided for an 8-VSB receiver.

Disclosure

Technical Problem

It is, therefore, an object of the present invention, which is developed to resolve the problems, to provide a Digital Television (DTV) transmitter and receiver that can reduce a signal-to-noise ratio (SNR) satisfying a Threshold of Visibility (TOV) by transmitting and receiving a double stream formed of normal data following an 8-level Vestigial Side Band (VSB) method, which will be simply referred to as 8-VSB method hereinafter, and robust data obtained after 16-state trellis coding to thereby improve a decoding capability of an equalizer and trellis decoder of a receiver and improve reception performance for receiving normal data as well as the robust data.

The other objects and advantages of the present invention can be easily recognized by those of ordinary skill in the art of the present invention from the drawing, detailed description, and claims of the present specification.

Technical Solution

In accordance with one aspect of the present invention, there is provided a digital television (DTV) transmitter, which includes: an input unit for receiving a digital video data stream including normal data and robust data; an encoding unit for coding the digital video data stream into data symbols; and a transmitting unit for modulating and transmitting an output signal of the encoding unit, wherein the encoding unit performs 16-state trellis coding on the robust data.

In accordance with another aspect of the present invention, there is provided a DTV receiver, which includes: a receiving unit for receiving a transmission signal including normal data and robust data and converting the received transmission signal into a baseband signal; an equalizing unit for determining a symbol level of the

transmission signal; a trellis decoding unit for performing trellis decoding on the symbol whose level has been determined; and a decoding unit for outputting a digital video data stream with respect to the trellis decoded signal, wherein the trellis decoding unit performs 16-state trellis decoding on the robust data.

In accordance with another aspect of the present invention, there is provided a DTV transmitting method, which includes the steps of: a) inputting a digital video data stream including normal data and robust data; b) coding the digital video data stream into data symbols; and c) modulating and transmitting an output signal of the encoding step b), wherein 16-state trellis coding is performed on the robust data in the encoding step b).

In accordance with another aspect of the present invention, there is provided a DTV receiving method, which includes the steps of: a) receiving a transmission signal including normal data and robust data and converting the received transmission signal into a baseband signal; b) determining a symbol level of the transmission signal; c) performing trellis decoding on the symbol whose level has been determined; and d) outputting a digital video data stream with respect to the trellis decoded signal, wherein 16-state trellis decoding is performed on the robust data in the trellis decoding step c).

In accordance with another aspect of the present invention, there is provided a DTV transmission signal, which includes: normal data mapped to any one data symbol of {-7,-5,-3,-1,1,3,5,7}; robust data which are trellis coded in 16 states and mapped to any one data symbol of {-7,-5,-3,-1,1,3,5,7}; and a robust data flag for identifying the normal data and the robust data, wherein the transmission signal is a Vestigial Side Band (VSB) modulated signal.

In accordance with the present invention, normal data

are transmitted in the 8-VSB method and robust data go through 16-state trellis coding. That is, part of 312 data segments of a data field are replaced with robust data packets instead of normal data packets, and the robust data symbols corresponding to the robust data packets are transmitted after trellis coding into 16 states. Since the preciseness of error signal calculation for updating a tap coefficient of an equalizer for the robust data transmitted from the receiver and the preciseness of a trellis decoder are improved, the reception performance of the general signal is improved as well as the SNR of the robust data.

The following description exemplifies only the principles of the present invention. Even if they are not described or illustrated clearly in the present specification, one of ordinary skill in the art can embody the principles of the present invention and invent various apparatuses within the concept and scope of the present invention.

The use of the conditional terms and embodiments presented in the present specification are intended only to make the concept of the present invention understood, and they are not limited to the embodiments and conditions mentioned in the specification.

In addition, all the detailed description on the principles, viewpoints and embodiments and particular embodiments of the present invention should be understood to include structural and functional equivalents to them. The equivalents include not only currently known equivalents but also those to be developed in future, that is, all devices invented to perform the same function, regardless of their structures.

For example, block diagrams of the present invention should be understood to show a conceptual viewpoint of an exemplary circuit that embodies the principles of the present invention. Similarly, all the flowcharts, state

conversion diagrams, pseudo codes and the like can be expressed substantially in a computer-readable media, and whether or not a computer or a processor is described distinctively, they should be understood to express various processes operated by a computer or a processor.

Functions of various devices illustrated in the drawings including a functional block expressed as a processor or a similar concept can be provided not only by using hardware dedicated to the functions, but also by using hardware capable of running proper software for the functions. When a function is provided by a processor, the function may be provided by a single dedicated processor, single shared processor, or a plurality of individual processors, part of which can be shared.

The apparent use of a term, 'processor', 'control' or similar concept, should not be understood to exclusively refer to a piece of hardware capable of running software, but should be understood to include a digital signal processor (DSP), hardware, and ROM, RAM and non-volatile memory for storing software, implicatively. Other known and commonly used hardware may be included therein, too.

Similarly, a switch described in the drawings may be presented conceptually only. The function of the switch should be understood to be performed manually or by controlling a program logic or a dedicated logic or by interaction of the dedicated logic. A particular technology can be selected for deeper understanding of the present specification by a designer.

In the claims of the present specification, an element expressed as a means for performing a function described in the detailed description is intended to include all methods for performing the function including all formats of software, such as combinations of circuits for performing the intended function, firmware/microcode and the like.

To perform the intended function, the element is

cooperated with a proper circuit for performing the software. The present invention defined by claims includes diverse means for performing particular functions, and the means are connected with each other in a method requested in the claims. Therefore, any means that can provide the function should be understood to be an equivalent to what is figured out from the present specification.

Advantageous Effects

As described above, the present invention can reduce a signal-to-noise ratio (SNR) satisfying a Threshold of Visibility (TOV) by transmitting and receiving a double stream formed of normal data following an 8- Vestigial Side Band (VSB) method and robust data obtained from trellis coding based on 16 states without increasing the average power regardless of the mixing ratio and improve reception performance for the normal data as well as the robust data.

Description of Drawings

The above and other objects and features of the present invention will become apparent from the following description of the preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram showing a conventional Digital Television (DTV) transmitter;

Fig. 2 is a block diagram illustrating a conventional DTV receiver;

Fig. 3 is a diagram describing a transmission data frame exchanged between the transmitter of Fig. 1 and the receiver of Fig. 2;

Fig. 4 is a block diagram showing a DTV transmitter in accordance with an embodiment of the present invention;

Fig. 5 is a block diagram depicting a robust

interleaver and a packet formatter of Fig. 4;

Fig. 6 is a diagram describing a robust data interleaver of Fig. 5;

Fig. 7 is a diagram illustrating a robust encoder of Fig. 4;

Fig. 8 is a diagram describing a robust encoder and a trellis encoder of Fig. 4;

Fig. 9 is a block diagram describing trellis coding of robust data which is suggested by a Philips Company;

Fig. 10 is a block diagram illustrating trellis coding of robust data in accordance with an embodiment of the present invention;

Fig. 11 is a block diagram illustrating trellis coding of robust data in accordance with another embodiment of the present invention;

Fig. 12 is a block diagram describing a robust data processor of Fig. 4;

Fig. 13 is a diagram showing a field synchronous segment of a data frame transmitted by the transmitter of Fig. 4;

Fig. 14 is a block diagram illustrating a DTV receiver in accordance with an embodiment of the present invention;

Fig. 15 is a block diagram showing a controller of Fig. 14;

Fig. 16 is a block diagram describing a packet formatter and a robust deinterleaver of Fig. 14; and

Fig. 17 is a diagram illustrating a robust data deinterleaver of Fig. 16.

Best Mode for the Invention

Other objects and aspects of the invention will become apparent from the following description of the embodiments with reference to the accompanying drawings, which is set forth hereinafter. If it is considered that further

description on the prior art may blur the points of the present invention, the description will not be provided. Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

Fig. 4 is a block diagram showing a Digital Television (DTV) transmitter in accordance with an embodiment of the present invention. As shown, the transmitter 400 includes: a first multiplexer 401, a data randomizer 403, a Reed Solomon (RS) encoder 405, a robust interleaver/packet formatter 407, a data interleaver 409, a robust encoder 411, a robust data processor 413, a trellis encoder 415, a second multiplexer 417, and a pilot adder/modulator/Radio Frequency (RF) converter 419.

The data randomizer 403, the RS encoder 405, the data interleaver 409, the trellis encoder 415, the second multiplexer 417, and a pilot adder/modulator/RF converter 419 are the same as the conventional data randomizer 101, the RS encoder 103, the data interleaver 105, the trellis encoder 107, the multiplexer 109, and a pilot adder 111, the Vestigial Side Band (VSB) modulator 113, and the RF converter 115, which were described with reference to Fig. 1.

The first multiplexer 401 multiplexes a normal data packet 421 and a robust data packet 423 under the control of a robust data flag signal 425.

A normal data packet 421 and a robust data packet 423 are serial data streams formed of 188-byte Moving Picture Experts Group (MPEG) compatible data packets and they have the same attributes, but the robust data packet includes an information packet and a null packet. A null packet includes arbitrary data, for example, "0," having a null packet header and it is added to secure a packet space to be extended based on a coding rate of robust data. In the present specification, the present invention will be

described based on an embodiment where the coding rate of robust data is 1/2, but the present invention should be understood that it is not limited to it.

The robust data flag signal 425 is generated in an external device (not shown) based on the ratio of robust data to normal data in a field, i.e., the Number of Robust Data Packets (NRP), and the coding rate of the robust data, e.g., 1/2 or 1/4. The other compositional elements of the transmitter 400 including the first multiplexer 401 can check out whether currently processed data are robust data by using the robust data flag signal 425.

The first multiplexer 401 multiplexes the normal data packet 421, the robust data packet 423, and the robust data flag signal 425 based on the number of robust data packets for each field. In accordance with an embodiment, the position of a robust data packet can be defined as an equation 1 according to the number of the robust data packets.

$$0 \le NRP/2 \le 39:$$
$$\{s \mid s=4i,\ i=0,1,\ldots,NRP-1\},\ (0 \le s \le 156)$$

$$40 \le NRP/2 \le 78:$$
$$\{s \mid s=4i,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i+2,\ i=0,1,\ldots,NRP-79\}$$

$$79 \le NRP/2 \le 117:$$
$$\{s \mid s=4i,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i+2,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i+1,\ i=0,1,\ldots,NRP-157\}$$

$$118 \le NRP/2 \le 156:$$
$$\{s \mid s=4i,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i+2,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i+1,\ i=0,1,\ldots,77\}\ U\ \{s \mid s=4i,\ i=0,1,\ldots,NRP-235\}$$

Eq. 1

In the equation 1, NRP denotes the number of robust segments occupied by robust data packets for each data

field, that is, the Number of Robust data Packets in a frame. As described above, the NRP is a value including all the number of information packet and null packets and it has a range of 0 to 312. Also, U signifies a union of two sets, and s denotes a data segment number in a data field and s has a range of 0 to 311.

In accordance with another embodiment, the position of a robust data packet can be defined as an equation 2.

$$\begin{aligned} RPI &= 312/NRP \\ RPP &= \mathrm{floor}(RPI \times r) \end{aligned} \qquad \text{Eq. 2}$$

In the equation 2, RPI stands for Robust Data Packet Interval and RPP denotes Robust Data Packet Position. Floor(*) is a decimal cutting operation, which means an operation cutting out a decimal number, for converting an arbitrary number * into an integer value, and a value r has a range of 0 to NRP.

According to the equation 2, when the NRP is 162 and the robust data coding rate is 1/2, the positions of normal data and robust data of a data field are determined as shown in Table 1.

Table 1

Packet Number	Packet Type
0	Robust
1	Robust (null)
2	General
3	Robust
4	General
5	Robust (null)
6	General
7	Robust
8	General
9	Robust (null)
10	General
11	Robust
12	General
13	Robust (null)
14	General
15	Robust
...	...
297	General
298	Robust
299	General
300	Robust (null)
301	General
302	Robust
303	General
304	Robust (null)
305	General
306	Robust
307	General
308	Robust (null)
309	General
310	Robust (null)
311	General

The general packet 421 and the robust data packet 423 multiplexed in the first multiplexer 401 are randomized in the data randomizer 403, and each packet is encoded to include a 20-byte parity information for Forward Error Correction (FEC) in the RS encoder 405. In the RS encoder 405, data having a total of 207 bytes, which are transmitted for each data segment, are generated by adding 20 RS parity bytes for FEC to the 187-byte data. A robust data flag does not go through the randomization and RS encoding. If a robust data packet is RS encoded and 20 RS parity bytes are added, a robust data flag is marked for the added RS parity bytes.

Subsequently, the RS-coded general and robust data packets are inputted to the robust interleaver/packet formatter 407 and only robust data including information packet are interleaved based on a robust data flag. The interleaved robust data are reconstructed into a 207-byte packet according to the robust data coding rate, and the reconstructed robust data packet is multiplexed with the normal data packet. The normal data packet has a predetermined delay to be multiplexed with the robust data packet.

Fig. 5 is a block diagram depicting a robust interleaver and a packet formatter of Fig. 4. As illustrated, the robust interleaver/packet formatter 407 includes a robust data interleaver 501, a packet formatter 503, and a third multiplexer 505.

The robust data interleaver 501 interleaves only a robust data packet based on a robust data flag signal. Fig. 6 is a diagram describing a robust data interleaver of Fig. 5. As shown, the robust data interleaver 501 receives signals on a byte basis with respect to a robust data packet only among data packets inputted from the RS encoder 405, performs interleaving to transmit the robust data to the packet formatter 503. Also, the robust data

interleaver 501 has parameters M=3, B=69 and N=207, and the interleaved packet can be formed of data from 69 different packets at maximum. Among the robust data packets, a null packet is abandoned and the interleaving is performed only on the information packets.

The packet formatter 503 shown in Fig. 5 processes the robust data interleaved in the robust data interleaver 501. The packet formatter 503 receives 184 bytes from the robust data interleaver 501 and generates two 207-byte data blocks with respect to the 184-byte robust data. Herein, four bits of each byte of the generated 207-byte data block, for example, LSB (6,4,2,0), corresponds to the inputted robust data. The other four bits, for example, MSB (7,5,3,1), are set up with arbitrary values. Meanwhile, in each of the generated 207-byte data blocks, the vacant positions that do not correspond to the 184-byte robust data are filled with header-byte data or arbitrary information data to be used for RS parity bytes, which will be described later on.

Subsequently, the packet formatter 503 adds a value obtained by randomizing a header corresponding to a null packet to the first three bytes of each 207-byte data block. Then, the packet formatter 503 generates a 207-byte packet by adding 20 bytes, each of which is formed of arbitrary information, for example, "0," to each data block. The 20-byte arbitrary information is replaced with RS parity information in the robust data processor 413, which will be described later.

All the other vacant byte positions can be filled with bytes of the 184-byte robust data sequentially. The packet formatter 503 checks out whether a position corresponds to a parity byte position, before it adds robust data bytes to each newly generated 207-byte data block. If the position does not correspond to a parity byte, a robust data byte is placed in the position. If the position corresponds to a parity byte, the byte position is skipped and the next byte

position is checked. The process is repeated until all the robust data bytes are placed in the newly generated 207-byte data block.

Therefore, if robust-interleaved four robust data packets (4 x 207 bytes) are inputted into the packet formatter 503, the packet formatter 503 outputs 9 packets (9 x 207 bytes) each of which is formed of robust data bytes, header bytes, and arbitrary information bytes for RS parity bytes. The outputted 9 packets include 92-bytes of the robust data inputted to the packet formatter 503, individually.

Meanwhile, the positions of arbitrary data bytes for RS parity bytes with respect to each packet are determined based on an equation 3.

$$m = (52 \times n + (s \bmod 52)) \bmod 207 \qquad \text{Eq. 3}$$

where m denotes an output byte number, i.e., a parity byte position of a packet extended into 207 bytes; n denotes an input byte, i.e., a byte number in each packet, and it ranges from 0 to 206; s denotes a segment corresponding to robust data in a data field, i.e., a packet number, and it ranges from 0 to 311. The parity byte positions, i.e., the value m, can be calculated only for the value n is in the range of 187 to 206 so that the positions of 20 parity packets for each packet should correspond to the last 20 bytes of the packet after data interleaving. In short, the value n corresponds to the last 20 bytes of a packet.

For example, when s=0 and n is in the range of 187 to 206, the parity byte positions for a packet 0 are given as 202, 47, 99, 151, 203, 48, 100, 152, 204, 49, 101, 153, 205, 50, 102, 154, 206, 51, 103, and 155. This signifies that the parity byte position should be the 202nd byte to make

the parity byte position ranged between 187 and 206 after interleaving in the data interleaver 409. Similarly, the position of another parity byte should be the 47th byte. However, according to the equation 3, a parity byte can be positioned in a position of a packet header byte. That is, the value m can be p, 1 and/or 2. Therefore, in order to prevent a parity byte from being positioned in the packet header byte position, the range of the value n can be increased as many as the number of parity bytes positioned for the header position. Accordingly, if a result value of $s \bmod 52$ is any one between 1 and 7 in calculation of 20 m values, part of the 20 m values becomes 0, 1 and/or 2.

For example, when $s \bmod 52 = 0$, all the 20 m values do not indicate parity byte positions, i.e., 0, 1 or 2, and thus all the 20 m values can be used for parity byte positions.

On the other hand, when $s \bmod 52 = 1$, one among the 20 m values indicate 0, which is a header byte position. In this case, the range of the value n is increased by 1 to be from 186 to 206. Therefore, 21 m values are calculated and a value m that comes in the header byte position is disused. The other 20 m values are designated to parity byte positions.

Likewise, when $s \bmod 52 = 2$, two out of 20 m values indicate 0 and 1, which are the header byte positions. In this case, the range of n is increased by two to be from 185 to 206. Accordingly, 22 m values are calculated and the values m corresponding to the header byte positions, i.e., 0 or 1, are disused. The other 20 m values are designated to parity byte positions.

Table 2 below shows the range of the value n based on the position of a robust data segment.

Table 2

$s \bmod 52$	Number of additional m values	Range of n

0	0	187 to 206
1	1	186 to 206
2	2	185 to 206
3	3	184 to 206
4	3	184 to 206
5	3	184 to 206
6	2	185 to 206
7	1	186 to 206
8 to 51	0	187 to 206

A third multiplexer 505 of Fig. 5 multiplexes a robust data packet and a normal data packet, which are outputted from the packet formatter 503, based on a robust data flag. The operation of the third multiplexer 505 is the same as that of the first multiplexer 401.

Referring to Fig. 4 again, the data interleaver 409 interleaves data packets within consecutive segments of each data field on a byte basis to scramble the sequential order of a robust data flag and general/robust data stream based on the ATSC A/53 standards and output scrambled data. Herein, the general/robust data and the robust data flag are interleaved through an independent interleaver, individually. The data interleaver 409 has a similar structure to the robust data interleaver 501 (see Fig. 6, M=4, B=52 and N=208).

Fig. 7 is a diagram illustrating a robust encoder of Fig. 4 in detail. As shown, the robust encoder 411 specifically includes a plurality of identical robust encoding units 411a to 411l in parallel. The robust encoder 411 performs trellis interleaving on the interleaved general/robust data and the interleaved robust data flag and performs coding on the trellis-interleaved general/robust data based on the trellis-interleaved robust data flag. The general/robust data outputted from the data interleaver 409 are inputted into the 12 robust encoding

units 411a to 411l sequentially on a byte basis, and two-bit general/robust data expressed as X1′ and X2′ are generated into two-bit general/robust data expressed as X1 and X2. For example, an input bit X2′ is a code word of MSB(7,5,3,1) and an input bit X1′ is a code word of LSB(6,4,2,0). As described above, although the MSB(7,5,3,1) and the LSB(6,4,2,0) of normal data all include information data, the LSB(6,4,2,0) of robust data includes information data and the MSB(7,5,3,1) of robust data includes arbitrary values.

The general/robust data coded in the robust encoding units goes through trellis deinterleaving, and the normal data bypass the robust data processor 413 and enter the trellis encoder 415, while the robust data pass through the robust data processor 413 and enter the trellis encoder 415. In this process, the normal data and the robust data coded in the 12 robust encoding units 411a to 411l are inputted into the trellis encoder 415 or the robust data processor 413 sequentially.

Referring to Fig. 4, the trellis encoder 415 is the same as the trellis encoder defined in the current ATSC A/53 Standards. Although not illustrated in the drawing, the trellis encoder 415, too, is formed of a plurality of identical trellis encoding units, for example, 12 identical trellis encoding units connected in parallel, just as the robust encoder 411. The normal data symbols X1 and X2 inputted into the trellis encoder 415 after bypassing the robust data processor 413 or the robust data symbols X1 and X2 inputted into the trellis encoder 415 through the robust data processor 413 are inputted into the 12 trellis encoding units, and the trellis encoder 415 performs trellis encoding on the inputted symbols X1 and X2 into 8-level symbols. The 8-level symbols obtained by being encoded in the 12 trellis encoding units are inputted into the second multiplexer 417 sequentially. This way, the

trellis encoding is carried out entirely.

Fig. 8 is a diagram describing a robust encoder and a trellis encoder of Fig. 4. Since the robust data processor 413 to be described later processes only robust data, Fig. 8 exemplifies conceptual connection between a robust encoding unit #0 411a and a trellis encoding unit #0 415a.

As defined in the current ATSC A/53 Standards, the trellis encoder 415 includes a pre-coding block, a trellis encoding block, and a symbol mapping block. The pre-coding block and the trellis encoding block includes registers D1, D2 and D3 for storing bit delay values, for example, 12 bit delay values.

The robust encoding unit #0 411a codes two-bit general/robust data X1′ and X2′ inputted from the data interleaver 409 into two-bit general/robust data symbols X1 and X2, and the trellis encoding unit #0 415a outputs 8-level signals to the second multiplexer 417 based on symbols Z0, Z1 and Z2 obtained by performing trellis encoding on the two-bit general/robust data symbols X1 and X2.

A method for coding robust data by using the robust encoder 411 and the trellis encoder 415 is already suggested by the Phillips Company.

Fig. 9 is a block diagram describing trellis coding of robust data which is suggested by a Philips company.

As described above, a robust encoder 911 outputs the trellis encoded symbols Z0, Z1 and Z2 in four levels by equalizing the coded values Z2 and Z1 of a trellis encoder 915 obtained through a precoder remover based on the value X1′ between the inputted signals X1′ and X2′.

The robust data coding method suggested by the Philips Company has a problem that the average power of symbols representing robust data is increased compared to the conventional 8-VSB method because the output symbols of the trellis encoder 915 use four levels {-7,-5,5,7}.

In other words, when robust data are mapped to any one among four-level symbols of {-7,-5,5,7}, the average power of symbols becomes 37energy/symbol, which is higher than the conventional 8-VSB method. The increase in the average power of the symbols indicating robust data increases the entire average power, and when a signal is transmitted with limited transmission output power, the transmission power of normal data is decreased relatively. Thus, the receiver comes to have inferior reception performance to the conventional 8-VSB method in the same channel environment.

The problem becomes more serious, as the rate of the robust data mixed with normal data increases. Thus, the SNR satisfying the TOV is increased. Accordingly, the reception performance can be degraded even though the channel environment is fine, and backward compatibility for a receiver based on the 8-VSB method may not be provided depending on circumstances.

Therefore, the present invention suggests a method that does not raise the symbol average power regardless of the rate of the robust data by using a 16-state trellis coding method with respect to robust data.

Fig. 10 is a block diagram illustrating trellis coding of robust data in accordance with an embodiment of the present invention.

As shown, an input signal X1′ is coded by adding registers D4 and D5 for generating robust data to a robust encoder 1011.

The output signal of a trellis encoder 1015 based on the input signal X1′ and the subsequent state are as shown in Tables 3 and 4.

Table 3

CURRENT STATE ↓ / INPUT →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	-7	-5	-7	-5	1	3	1	3	-3	-1	-3	-1	5	7	5	7
1	1	3	1	3	-7	-5	-7	-5	5	7	5	7	-3	-1	-3	-1

Table 4

CURRENT STATE ↓ / INPUT →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	2	1	3	0	2	1	3	5	7	4	6	5	7	4	6
1	12	14	13	15	12	14	13	15	9	11	8	10	9	11	8	10

The 16 states of Table 16 are calculated based on an equation 4.

$$S = D_4 \times 8 + D_5 \times 4 + D_2 \times 2 + D_3 \qquad \text{Eq. 4}$$

Meanwhile, the state values of the registers D4 and D5 additionally used to generate robust data are not changed when normal data are inputted, and the output signals based on input and the subsequent state are as shown in Tables 5 and 6.

Table 5

CURRENT STATE ↓ / INPUT →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3	-7, 1	-5, 3
1	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7	-3, 5	-1, 7

Table 6

CURRENT STATE \ INPUT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	2	1	3	4	6	5	7	8	10	9	11	12	14	13	15
1	1	3	0	2	5	7	4	6	9	11	8	10	13	15	12	14

When robust data are generated by using 16-state trellis coding in accordance with the present embodiment, the performance of a receiver can be improved by designing a trellis decoder and a signal level detector with reference to the Tables 3 and 4.

Fig. 11 is a block diagram illustrating trellis coding of robust data in accordance with another embodiment of the present invention.

As shown, an input signal X1′ is coded by adding registers D4 and D5 for generating robust data to a robust encoder 1111.

The output signal of a trellis encoder 1115 based on the input signal X1′ and the subsequent state are as shown in Tables 7 and 8.

Table 7

CURRENT STATE \ INPUT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	-7	-5	-7	-5	-3	-1	-3	-1	1	3	1	3	5	7	5	7
1	1	3	1	3	5	7	5	7	-7	-5	-7	-5	-3	-1	-3	-1

Table 8

CURRENT STATE \ INPUT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	2	1	3	9	11	8	10	0	2	1	3	9	11	8	10
1	12	14	13	15	5	7	4	6	12	14	13	15	5	7	4	6

The 16 states of Table 7 are calculated based on the equation4.

Meanwhile, the state value of the registers D4 and D5 additionally used to generate the robust data are not changed, when normal data are inputted, and the output signal based on the input and the subsequent state are as shown in the Tables 5 and 6.

When robust data are generated by using 16-state trellis coding in accordance with the present embodiment, the performance of a receiver can be improved by designing a trellis decoder and a signal level detector with reference to the Tables 7 and 8.

Fig. 12 is a block diagram describing a robust data processor of Fig. 4. As illustrated, the robust data processor 413 includes a data deinterleaver 1203, an RS encoder 1205, and a data interleaver 1207. The robust data X1 and X2 and a robust data flag which are outputted from the robust encoder 411 are deinterleaved in a data deinterleaver 1203 and reassembled in the form of a packet.

As described above, 20-byte arbitrary information is added to the 207-byte data block generated in the packet formatter 503, and the RS encoder 1205 replaces the 20-byte arbitrary information with RS parity information. The robust data packet with the RS parity information therein is interleaved in the data interleaver 1207 and outputted to the trellis encoder 415 on a byte basis.

Referring to Fig. 4 again, normal data and robust data are combined with a segment synchronization bit sequence and a field synchronization bit sequence, which are transmitted from a synchronization unit (not shown), in the second multiplexer 417 to thereby generate a transmission data frame. Subsequently, a pilot signal is added in the pilot adder. A symbol stream is modulated into VSB-suppressed carrier in a VSB modulator. A 8-VSB symbol

stream of a baseband is converted into a radio frequency signal in an RF converter after all and transmitted.

Fig. 13 is a diagram showing a field synchronous segment of a data frame transmitted by the transmitter of Fig. 4. As shown in the drawing, a segment transmitted from the transmitter 400 is basically the same as the segment of the ATSC A/53 Standards. If any, in a reserved field corresponding to the last 104 symbols of a segment, 92 symbols except precode 12 symbols contains information for restoring the robust data packet. The information for restoring the robust data packet includes an NRP, which is a ratio of robust data to normal data within a field, and a coding rate information of the robust data, e.g., 1/2 or 1/4. As to be described later, a receiver suggested in the embodiment of the present invention generates a robust data flag out of the information for restoring the robust data packet, and constitutional elements of the receiver can check out whether currently processed data are robust data or not by using the robust data flag.

Fig. 14 is a block diagram illustrating a DTV receiver in accordance with an embodiment of the present invention. As shown, a receiver 1400 includes a tuner 1401, an IF filter and detector 1403, an NTSC removing filter 1405, an equalizer 1407, a trellis decoder 1409, a data deinterleaver 1411, a packet formatter/robust deinterleaver 1413, an RS decoder 1415, a data derandomizer 1417, a demultiplexer 1419, a synchronous and timing recovery block 1421, a field synchronous decoder 1423, and a controller 1425.

The tuner 1401, the IF filter and detector 1403, the NTSC removing filter 1405, the data deinterleaver 1411, the RS decoder 1415, the synchronous and timing recovery block 1421 perform the same functions as the tuner 201, the IF filter and detector 203, the NTSC removing filter 205, the data deinterleaver 211, the RS decoder 213, and the

synchronous and timing recovery block 215.

The field synchronous decoder 1423 receives a segment of a data frame illustrated in Fig. 13, restores the robust data packet restoring information in the reserved area, which includes information on the rate of robust data and normal data within a field and information on the coding rate of the robust data, and transmits it to the controller 1425.

Fig. 15 is a block diagram showing a controller of Fig. 14. As shown, the controller 1425 includes a general/ robust data identifying flag generator 1501, a data interleaver 1503, a trellis interleaver 1505, a delay buffer 1507, and a delay calculator 1509.

The general/robust data identifying flag generator 1501 generates a robust data flag by using the robust data packet restoring information transmitted from the field synchronous decoder 1423.

The generated robust data flag goes through a bit-unit data interleaving and trellis interleaving based on the ATSC A/53 in the data interleaver 1503 and the trellis interleaver 1505 and the interleaved robust data flag is transmitted to the equalizer 1407 and the trellis decoder 1409. The robust data flag included in the data frame transmitted from the transmitter 400 is already interleaved through the data interleaving and the trellis interleaving, the equalizer 1407 and the trellis decoder 1409 performs equalization and trellis decoding based on the interleaved robust data flag obtained from the data interleaving and the trellis interleaving.

Meanwhile, the delay buffer 1507 receives the robust data flag generated in the general/ robust data identifying flag generator 1501 and transmits the robust data flag to the packet formatter/robust deinterleaver 1413 in consideration of delay generated while data are processed in the trellis decoder 1409 and the data deinterleaver 1411.

Also, the delay buffer 1507 transmits the robust data flag to the data derandomizer 1417, the demultiplexer 1419, and the delay calculator 1509, individually, in consideration of delay generated while data are processed in the packet formatter/robust deinterleaver 1413.

The delay calculator 1509 calculates delay time of a robust data packet by using the robust data flag, which is obtained in consideration of delay with respect to normal data generated while robust data are processed in the packet formatter/robust deinterleaver 1413 and transmitted from the delay buffer 1507, and the robust data packet restoring information, which is transmitted from the field synchronous decoder 1423, and transmits the calculated delay time to the data derandomizer 1417. The data derandomizer 1417 is synchronized with a field synchronous signal of a data frame and performs derandomization. The robust data packet restoring information transmitted from the field synchronous decoder 1423 includes information on the position of the robust data packet in the data frame. However, the packet formatter/robust deinterleaver 1413 can process only a robust data packet and, particularly, the deinterleaving process carried out in the robust deinterleaver delays the robust data packet by a few packets. The delay calculator 1509 calculates delay time with respect to the robust data packet based on the received robust data packet restoring information and the robust data flag to compensate for the delay in the robust data packet and transmits the delay time to the data derandomizer 1417. The data derandomizer 1417 derandomizes a normal data packet and a robust data packet based on the received robust data flag and the delay time with respect to the robust data packet. For example, when the n^{th} normal data packet is derandomized, the next robust data packet to be derandomized is not the $(n+1)^{th}$ robust data packet but it can be the k^{th} robust data packet $(k<n)$. The delay of the

robust data packet is longer than that of the normal data packet, because the delay generated for restoring into the original packet is included. Therefore, the data derandomizer 1417 should perform the derandomization in consideration of the delay.

Fig. 16 is a block diagram describing a packet formatter and a robust deinterleaver of Fig. 14, and Fig. 17 is a diagram illustrating a robust data deinterleaver of Fig. 16. The packet formatter and a robust deinterleaver is operated in opposite to the robust interleaver/packet formatter 407 of the transmitter 400 illustrated in Fig. 5. That is, it removes 20 RS parity bytes and three header bytes included in the robust data segment 207 inputted from the data deinterleaver 1411 and separates robust data packets including information data from null packets. Thus, when a robust data segment having 9 packets (9x207 bytes) is inputted into a packet formatter 1601, the packet formatter 1601 outputs four robust data packets which are formed of information data and five null packets formed of null data. Subsequently, a robust data deinterleaver 1603 receives the robust data packets inputted from the packet formatter 1601 on a byte basis, performs deinterleaving, and transmits the robust data packets to a multiplexer 1605. During the deinterleaving, null packets among the robust data packets are abandoned and the deinterleaving is carried out only on information packets. A normal data packet has a predetermined delay to be thereby multiplexed with a robust data packet.

The multiplexed normal data packet and robust data packet are transmitted to the RS decoder 1415. The RS decoder 1415 performs RS decoding with respect to each packet and transmits the resultant to the data derandomizer 1417.

With reference to Fig. 14 again, the demultiplexer 1419 demultiplexes the normal data packet and the robust

data packet based on the robust data flag and outputs them in a form of a serial data stream formed of a 188-byte MPEG compatible data packet.

For the equalizer 1407, a known determiner, which is known as a slicer, or a trellis decoder with a trace back of zero (0).

The equalizer 1407 equalizes a received signal based on the interleaved robust data flag obtained from the bit-based data interleaving and the trellis interleaving based on the ATSC A/53 and transmitted from the controller 1425.

In short, in case of a normal data signal, the signal level is determined in four states with respect to an 8-level {-7,-5,-3,-1,1,3,5,7}, which is the same as the conventional technology. In case of a robust data signal, the signal level is determined with respect to an 8-level {-7,-5,-3,-1,1,3,5,7} which is trellis coded in 16 states. That is, as for a robust data signal, the 8-level {-7,-5,-3,-1,1,3,5,7} which is trellis coded in 16 states is used as decision data used to update a tap coefficient of the equalizer 1407. For example, the trellis decoder used in the equalizer 1407 determines a signal level based on the 16 states shown in Tables 3 and 4 or Tables 7 and 8. Since precise signal level determination increases a convergence speed of the equalizer, it can improve reception performance for robust data as well as normal data in a Doppler environment.

The trellis decoder 1409 may be a trellis decoder based on the ATSC A/53 or it can be similar to the trellis decoder that can be used in the equalizer 1407. That is, with respect to a normal data signal, 4-state trellis decoding is carried out on an 8-level signal {-7,-5,-3,-1,1,3,5,7}, which is the same as the conventional technology. With respect to a robust data signal, trellis decoding is performed on the 8-level signal which is trellis coded in 16 states and shown in Tables 3 and 4 or

Tables 7 and 8.

According to the present invention, the 8-VSB receiver based on the ATSC A/53 can receive a normal data packet and it can provide backward compatibility by processing a robust data packet as a null packet.

While the present invention has been described with respect to certain preferred embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the scope of the invention as defined in the following claims.